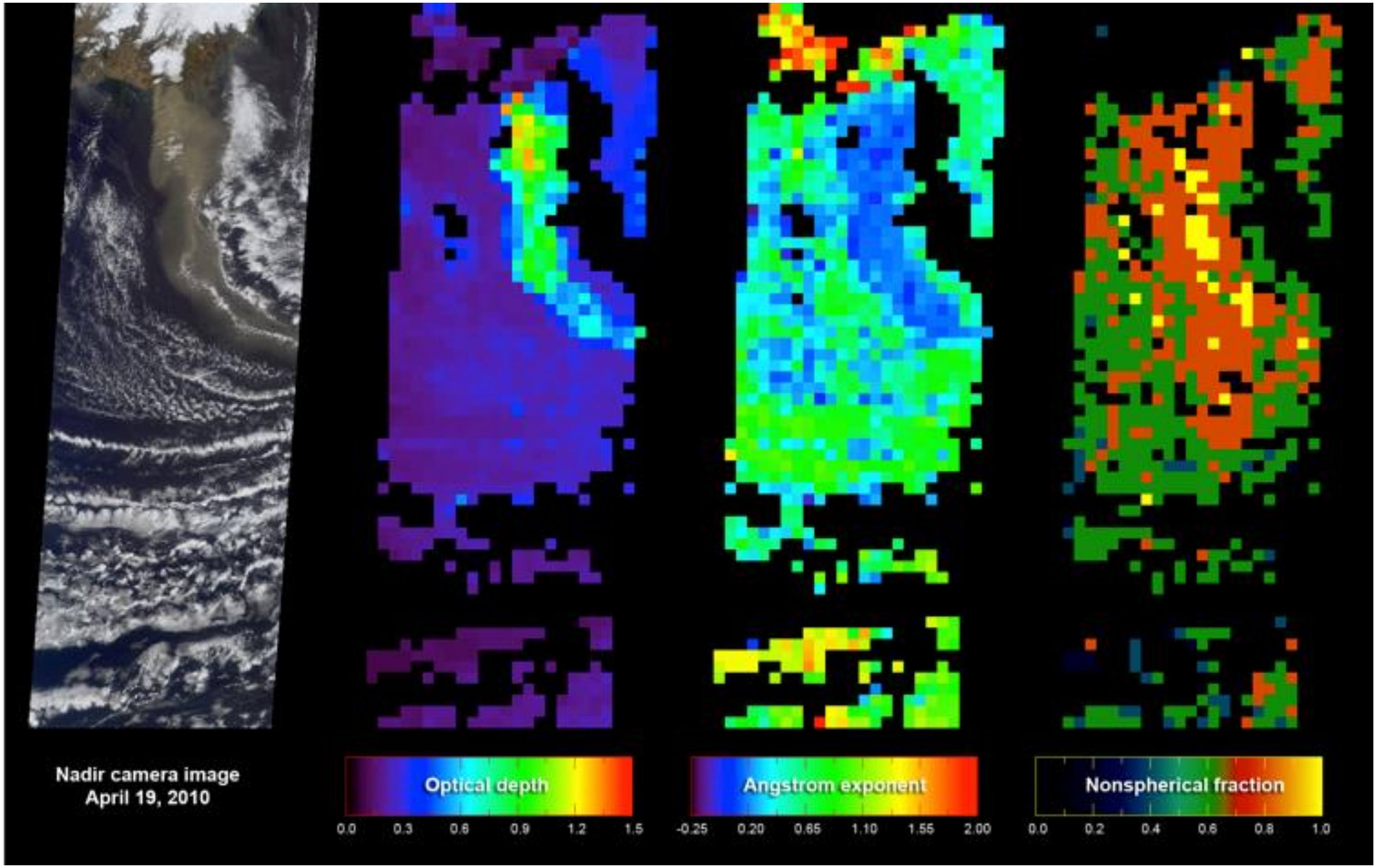
MISR Eyjafjallajökull & Grimsvötn Retrievals

Ralph Kahn & James Limbacher

NASA Goddard Space Flight Center



Eyjafjallajökull Volcano Ash Plume – MISR Aerosol Retrieval – April 19, 2010

MISR Team, JPL and GSFC

Multi-angle Imaging SpectroRadiometer

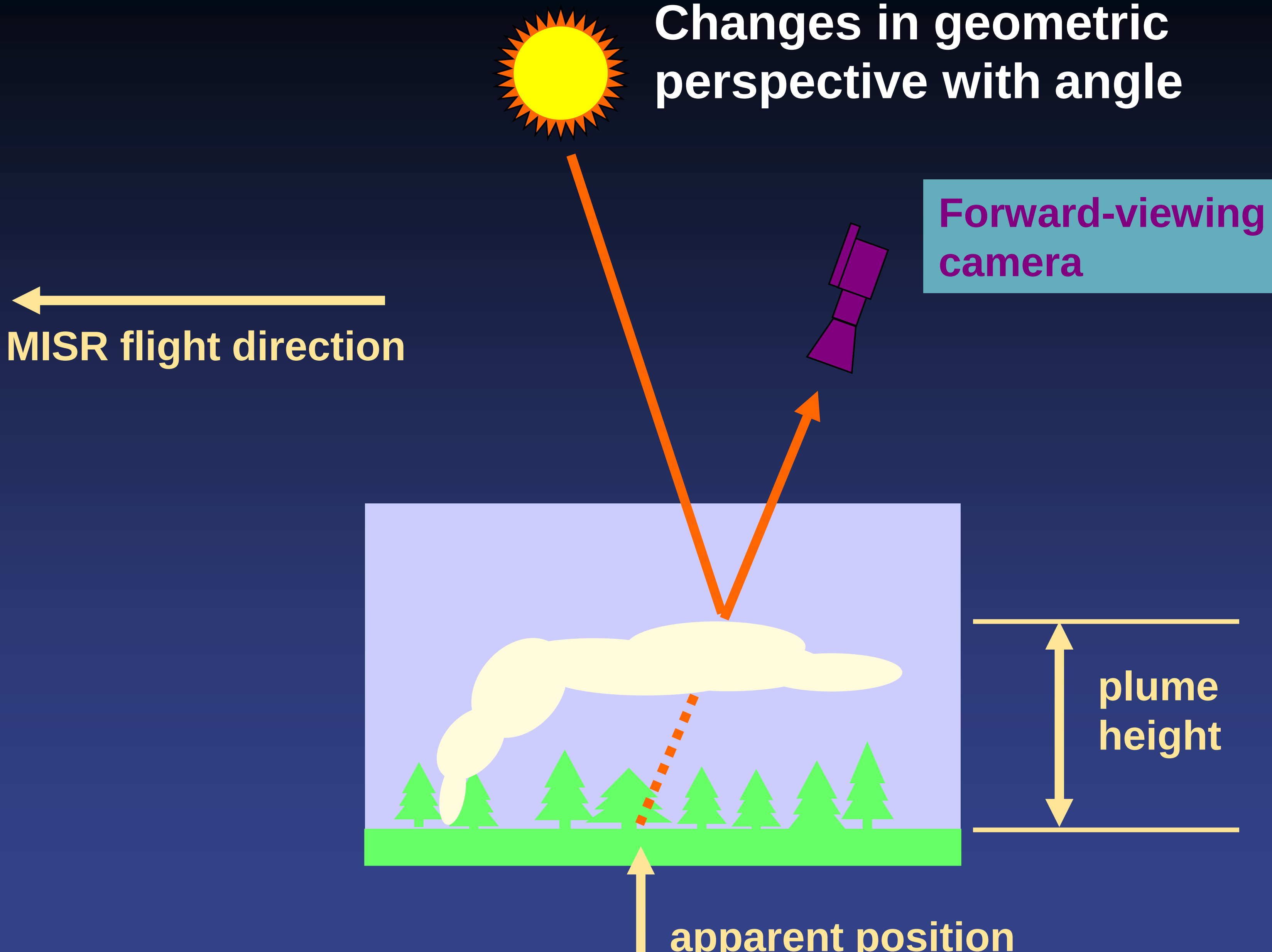
MISR

http://www-misr.jpl.nasa.gov

http://eosweb.larc.nasa.gov

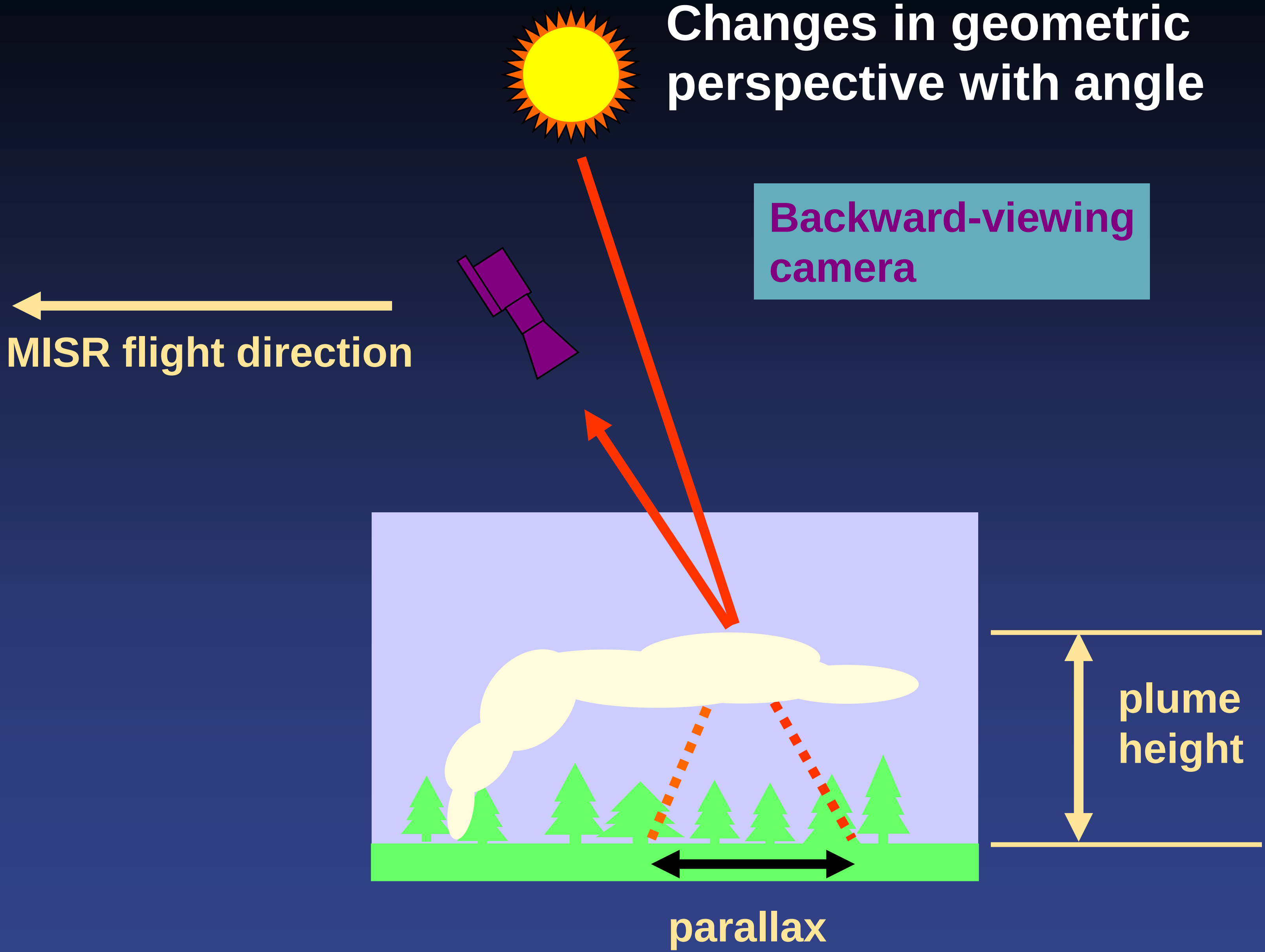
- **<u>Nine</u> CCD push-broom <u>cameras</u>**
- **<u>Nine</u> <u>view</u> <u>angles</u> at Earth surface:**
  70.5º forward to 70.5º aft
- **<u>Four</u> <u>spectral</u> <u>bands</u> at each angle:**
  446, 558, 672, 866 nm
- **Studies *Aerosols*, *Clouds*, & *Surface***

Changes in geometric perspective with angle



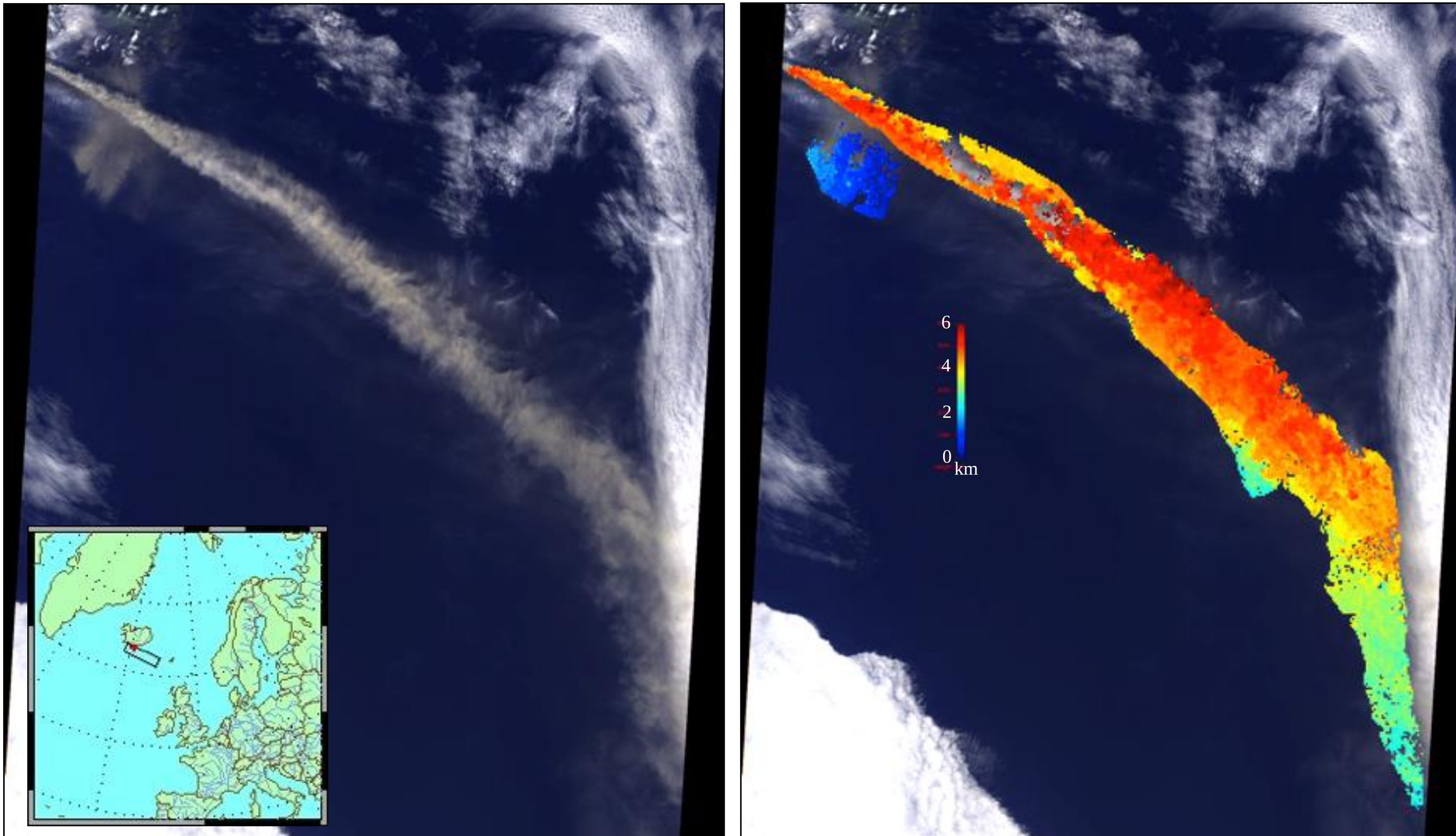
Diner & Kahn, 2003

Changes in geometric perspective with angle



Diner & Kahn, 2003

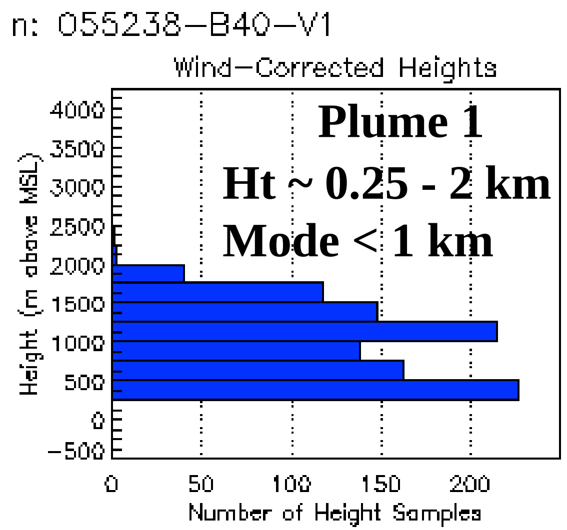
Eyjafjallajökull Volcano
MISR Stereo-Derived Plume Heights
07 May 2010 Orbit 55238 Path 216 Blks 40-43 UT 12:39



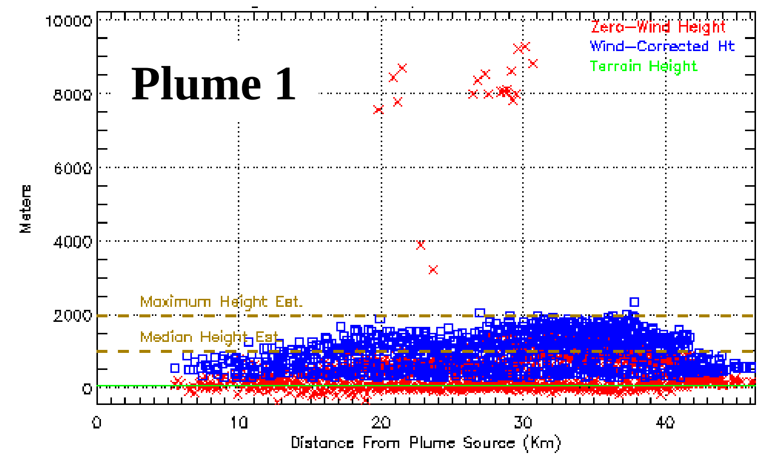
D. Nelson and the MISR Team, JPL and GSFC

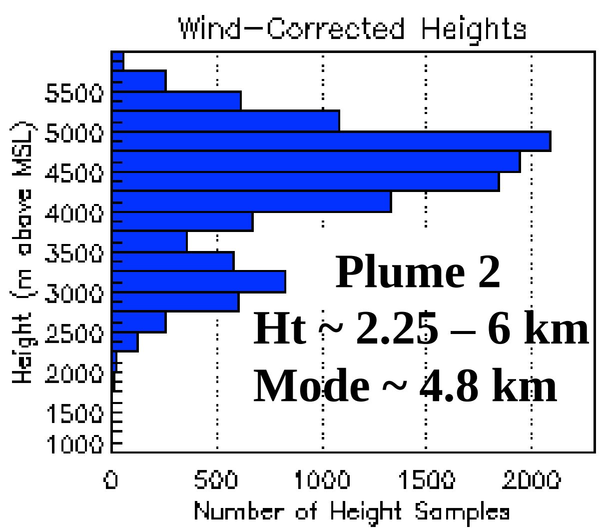
Eyjafjallajökull Volcano
MISR Stereo-Derived Plume Heights

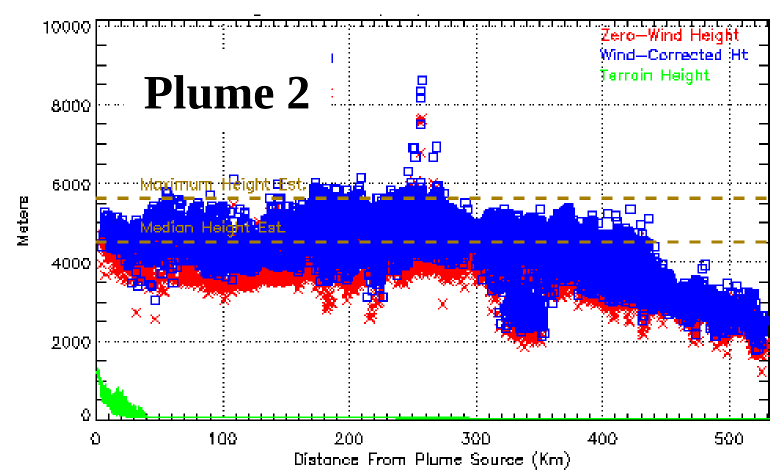
***07 May 2010* Orbit 55238 Path 216 Blks 40-43 UT 12:39**



Height: Blue = Wind-corrected

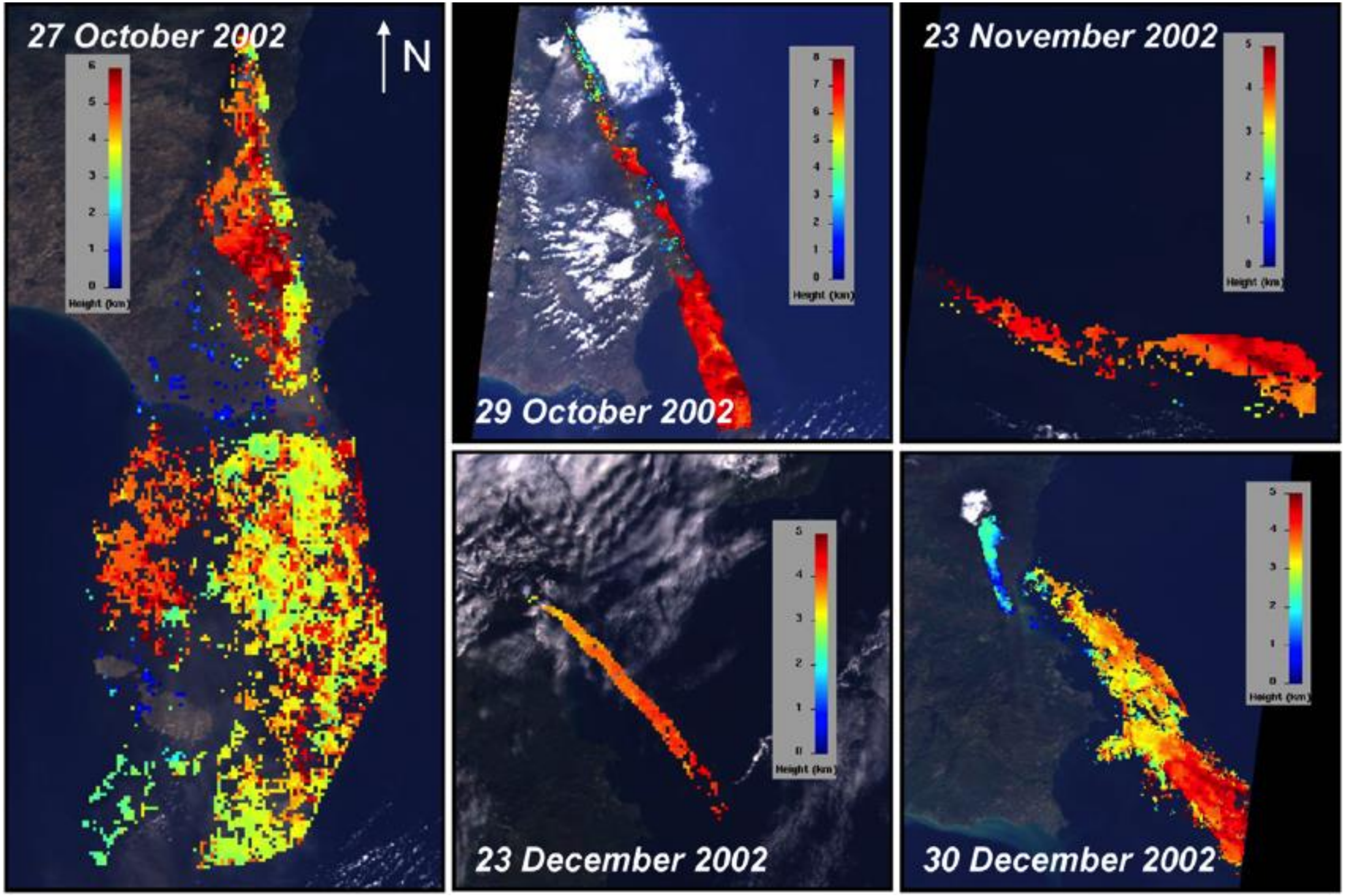






D. Nelson and the MISR Team

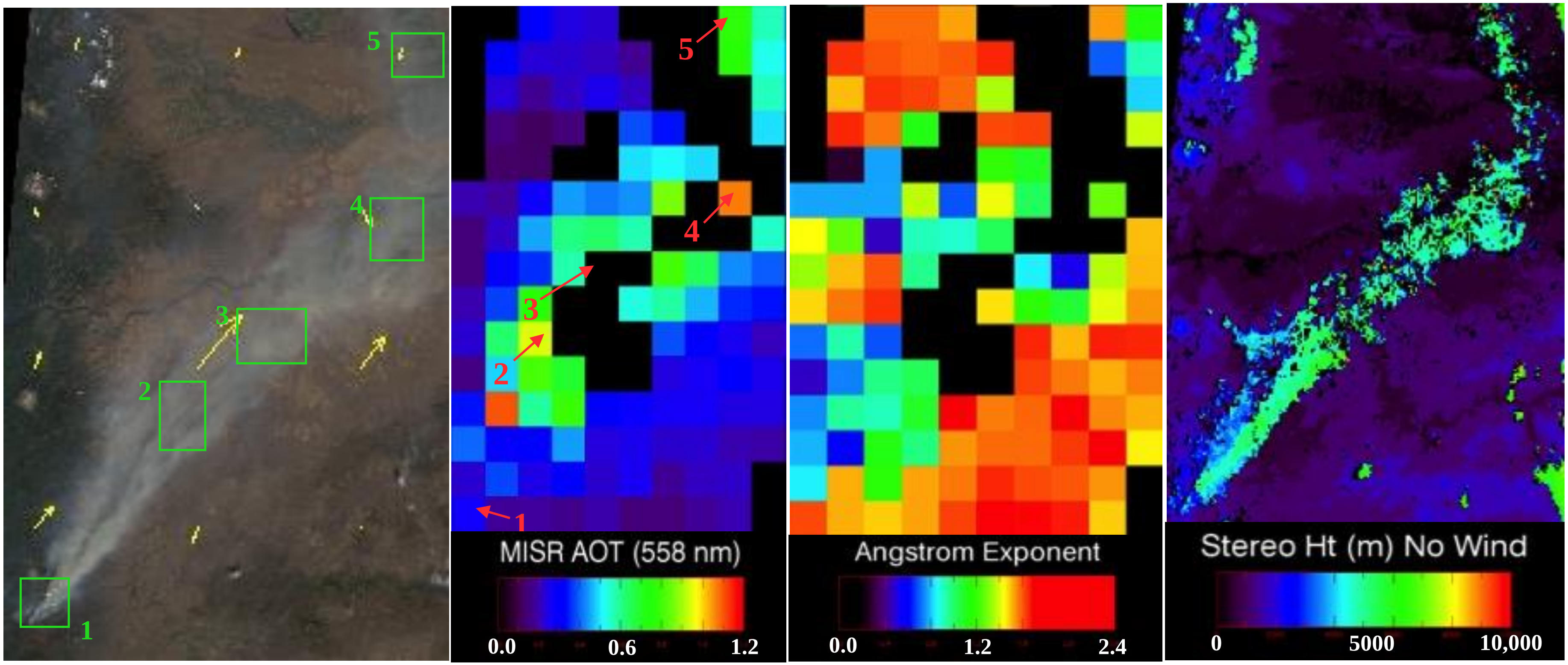
Etna Volcano
MISR Stereo-Derived ***Plume Heights***

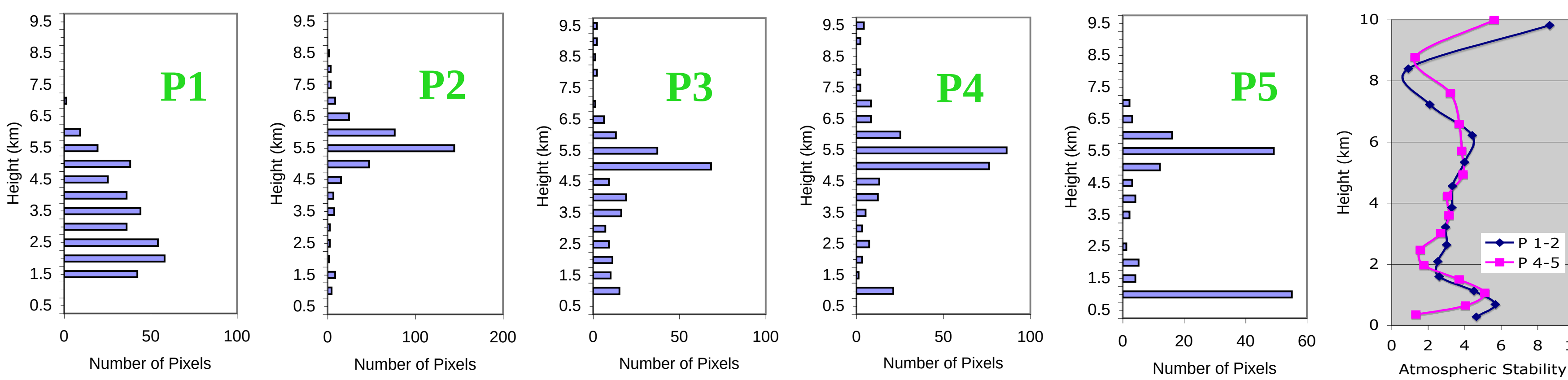


Scollo et al., JGR 2012

Oregon Fire Sept 04 2003

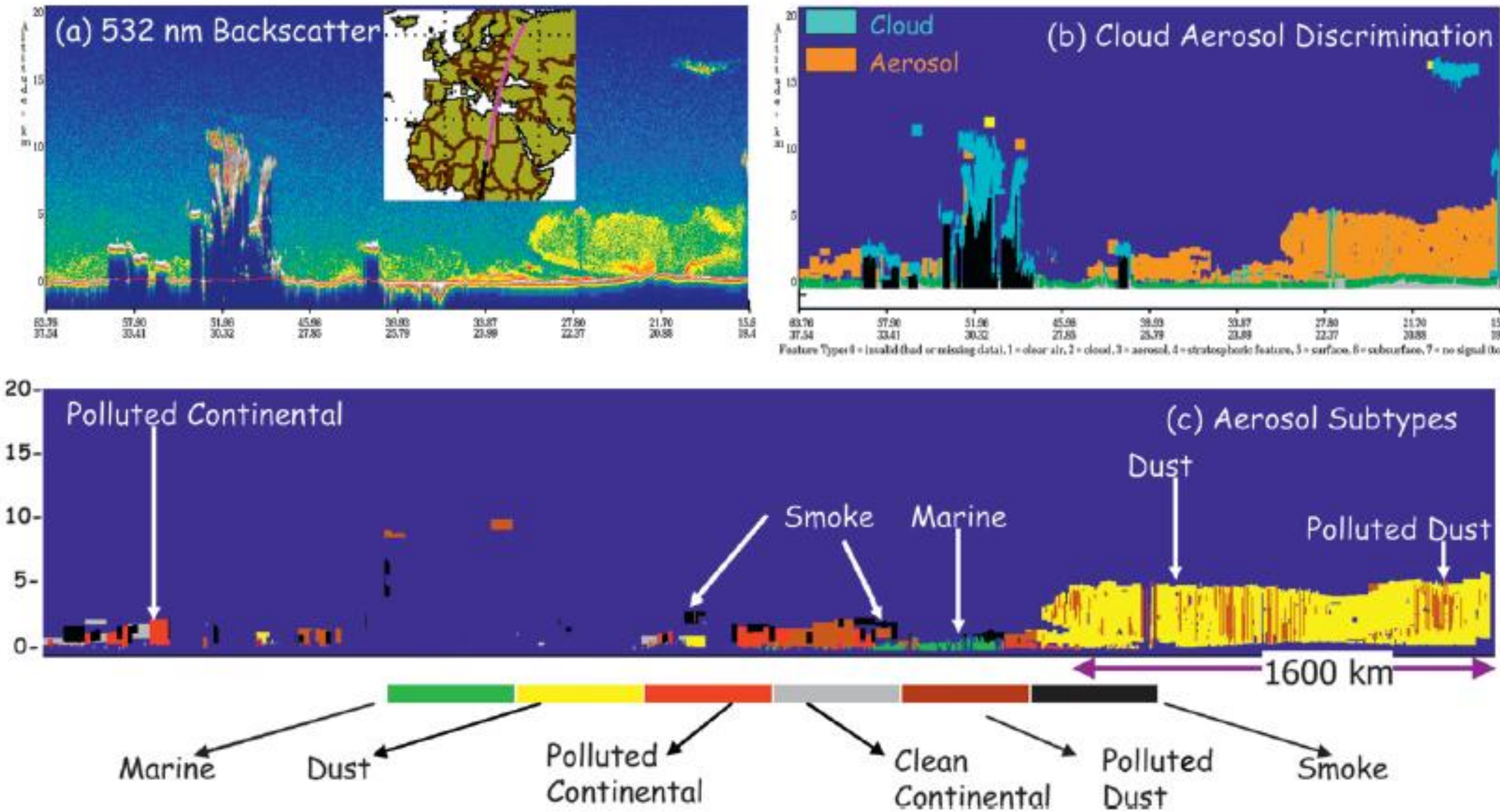
Orbit 19753 Blks 53-55 MISR Aerosols V17, Heights V13 (no winds)





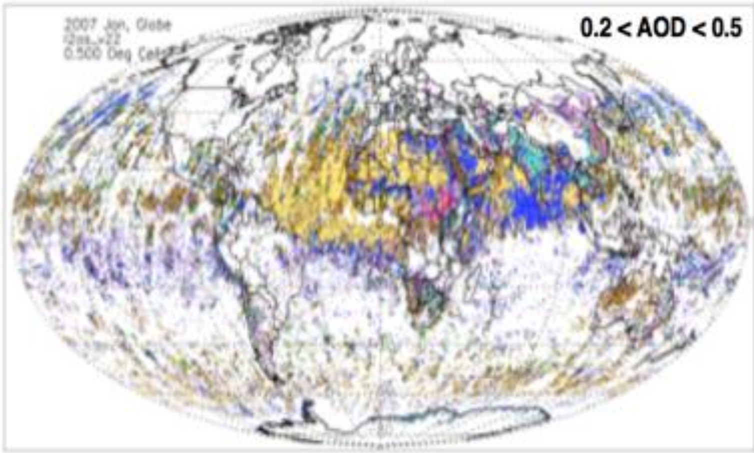
Kahn, et al., JGR 2007

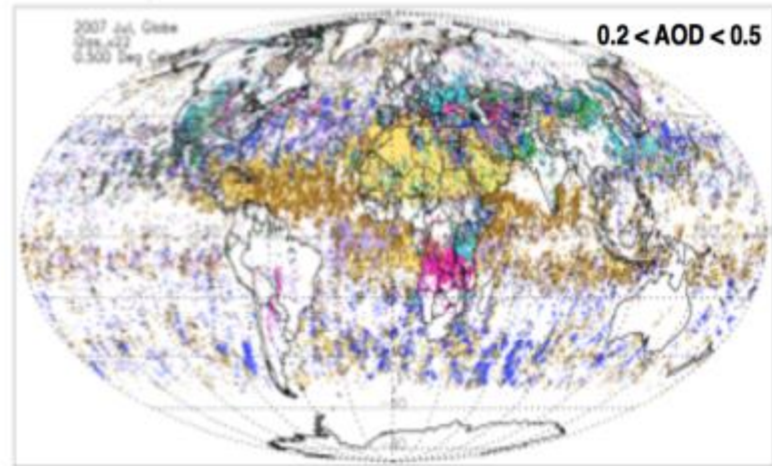
The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO)



Omar et al., JAOT 2009

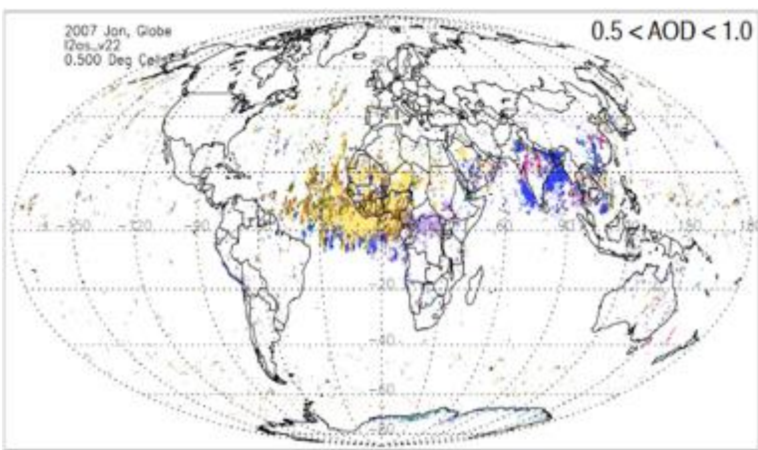
MISR Aerosol Type Discrimination

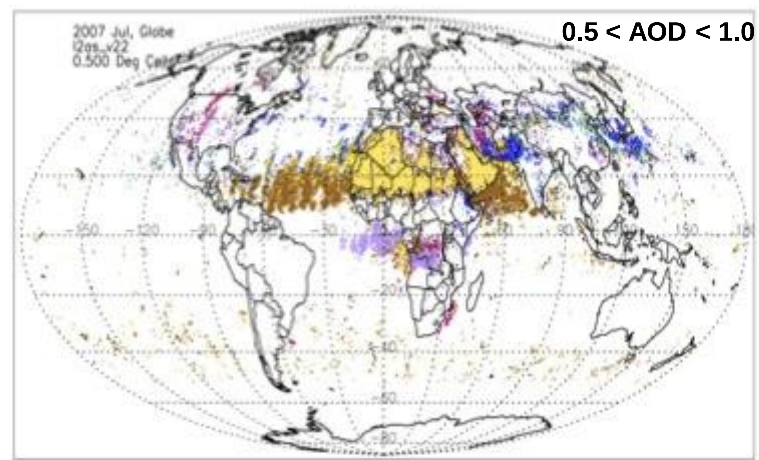




January 2007

July 2007





1-10 11-20 21-30 31-40 41-50 51-62 63-70 71-74 Mixture Group

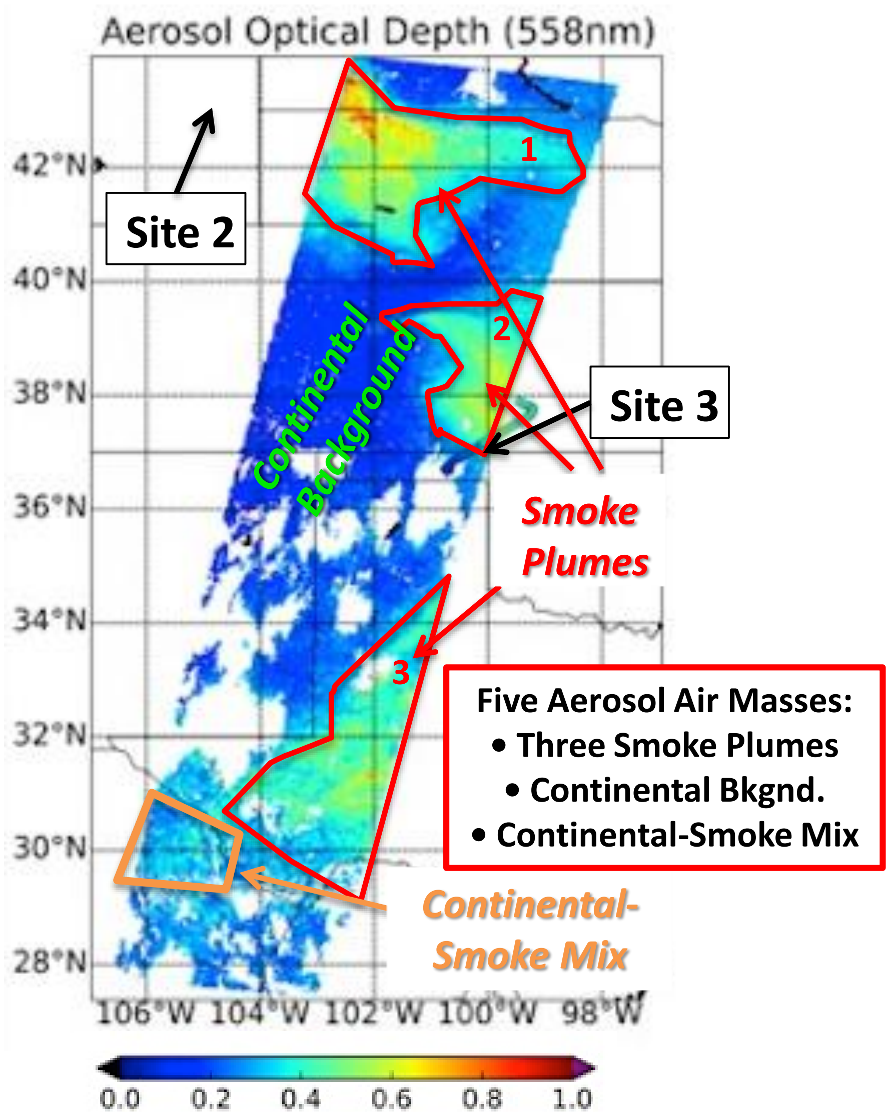
Spherical, non-absorbing

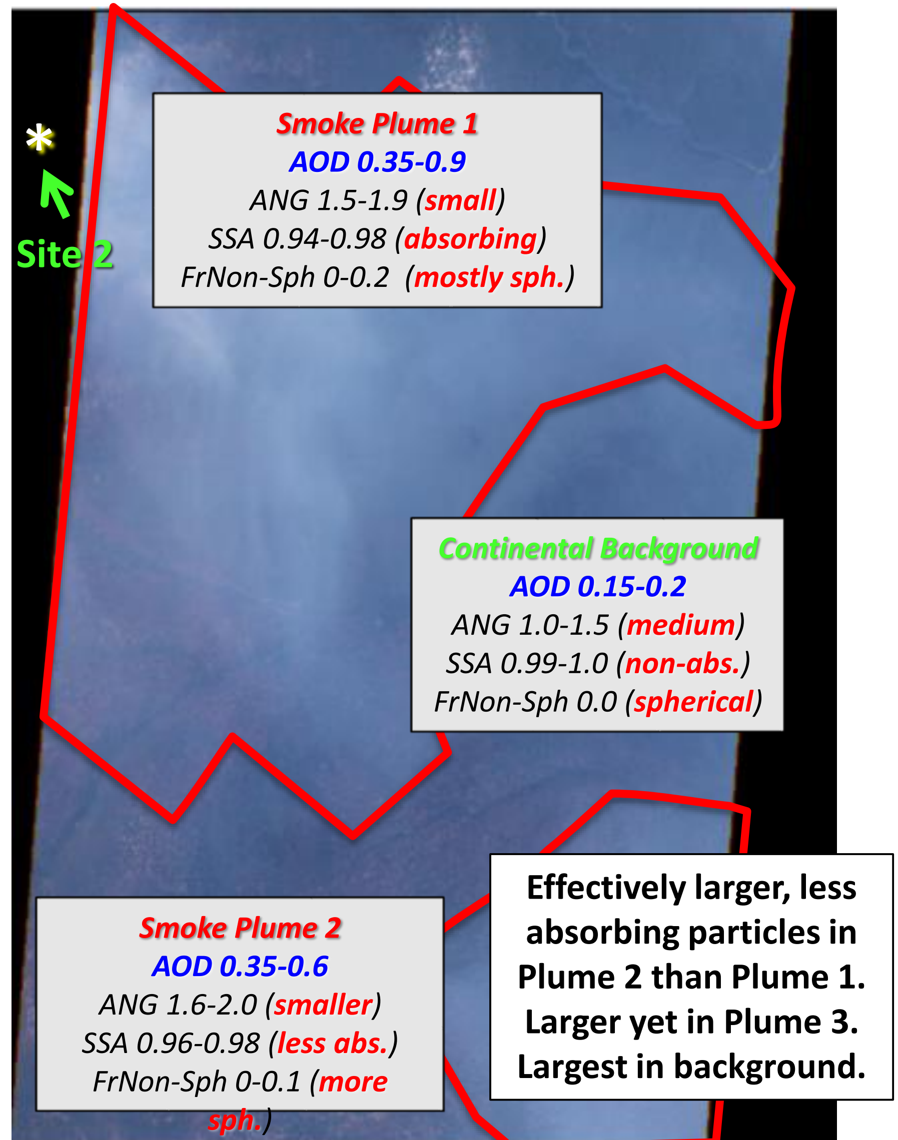
Non-spherical

Spherical, absorbing

Kahn & Gaitley JGR 2015

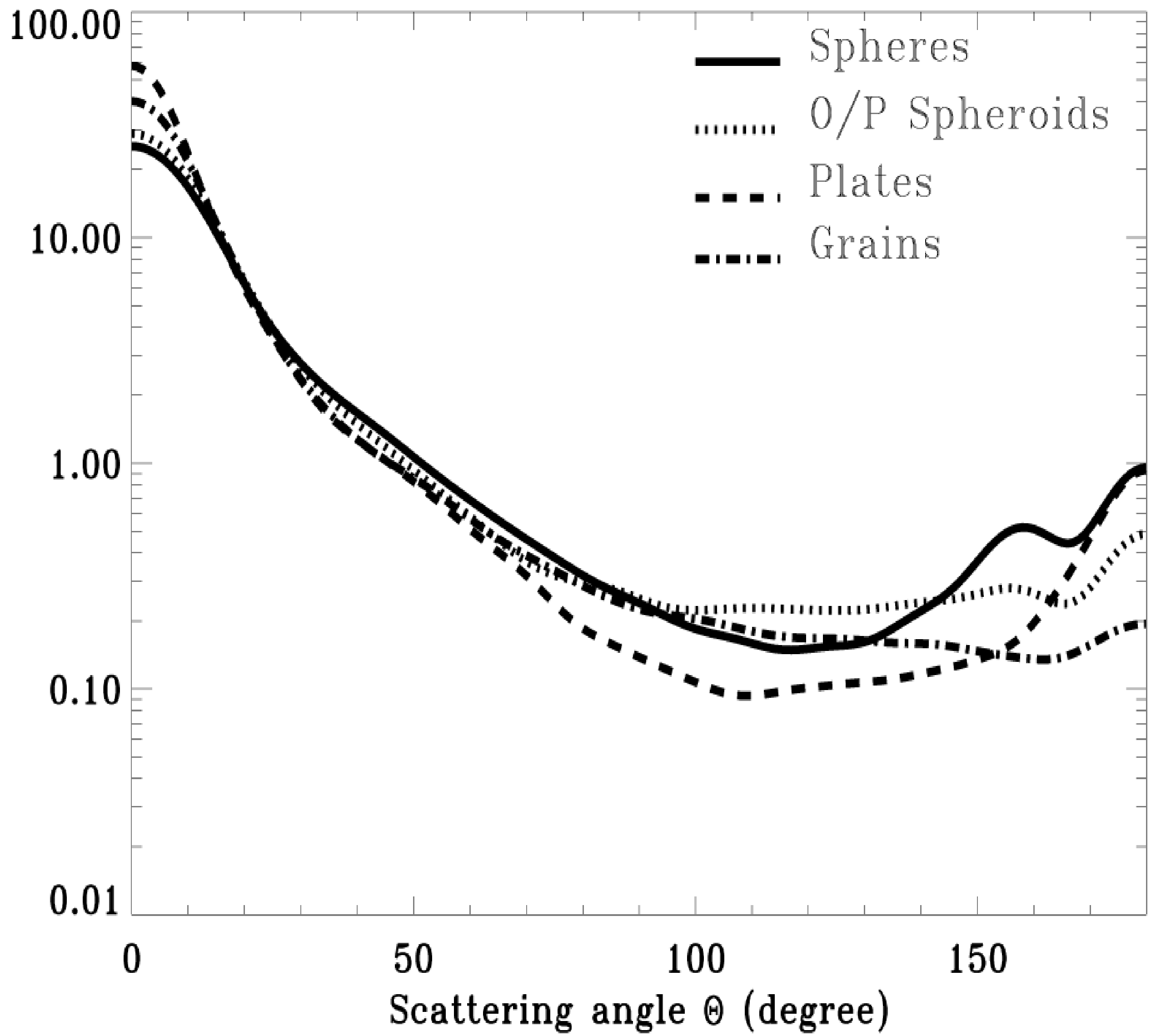
SEAC^{4}RS – MISR Overview 19 August 2013





Passive-remote-sensing ***Aerosol Type*** is a ***Total-Column-Effective***, ***Categorical*** variable!!

Single-scattering Phase Functions for Different Particle **Shapes**



Kalashnikova & Kahn, JGR 2006

Single-scattering Phase Functions for Different Particle Types

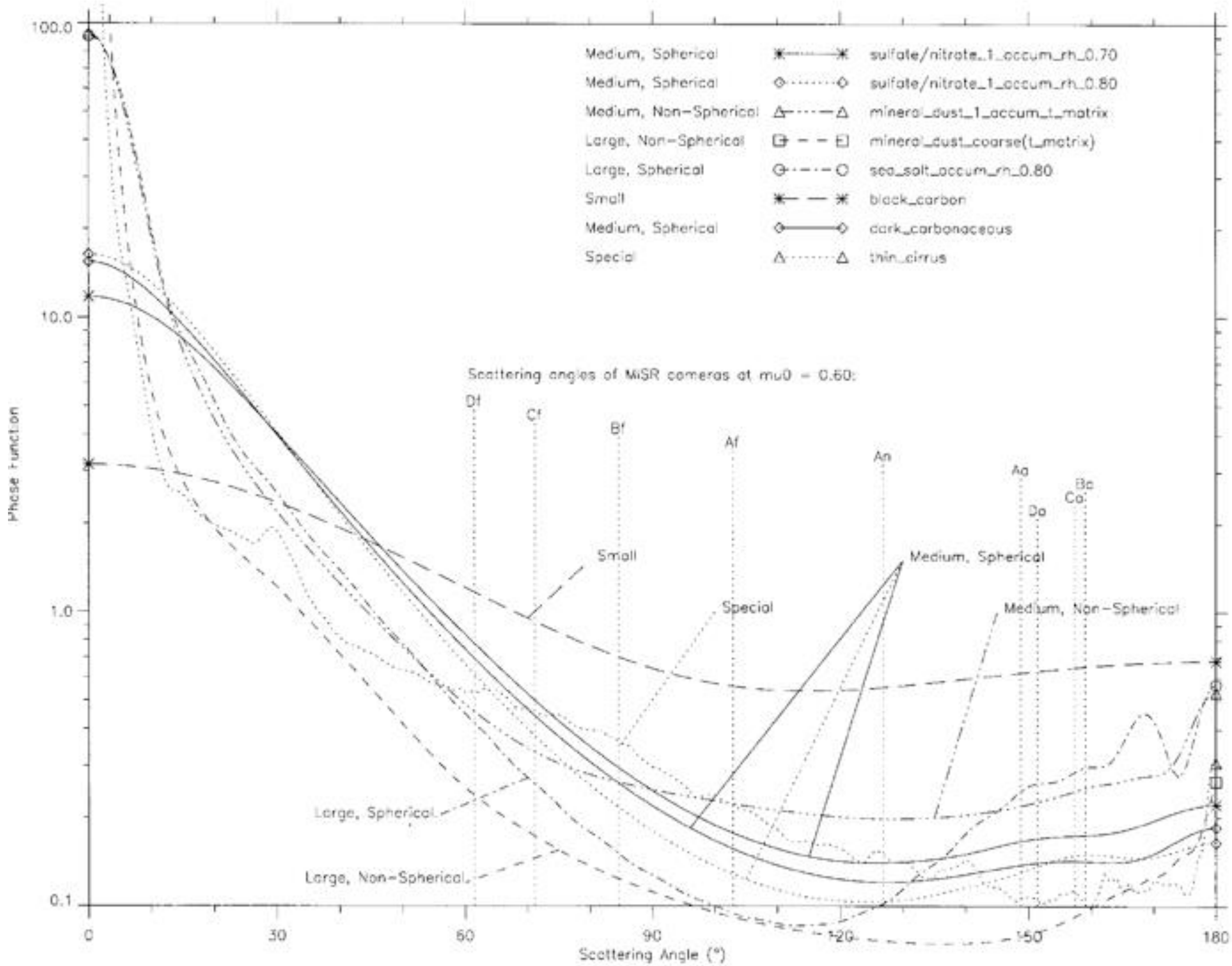
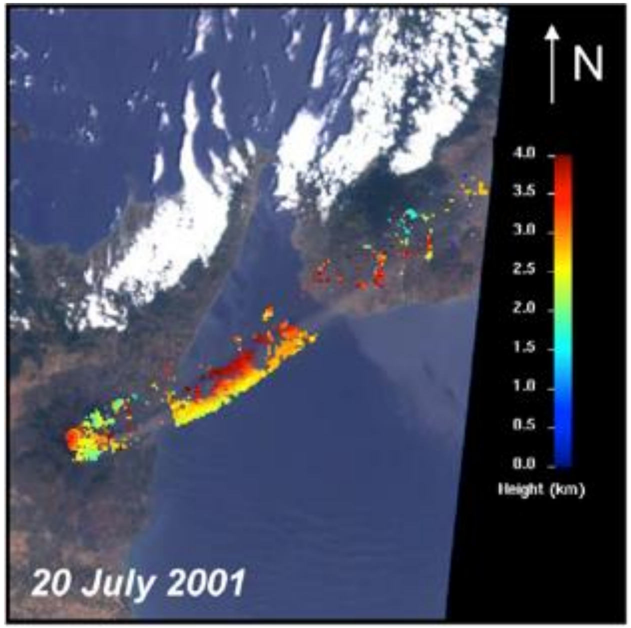


Figure 1. Single-scattering phase functions for six particle types (including two hydration states for sulfate particles) and thin cirrus, for MISR band 3 (672 nm effective wavelength). Detailed physical properties for these particles are given in Table 3. Superposed on this plot are the scattering angles sampled by the nine MISR cameras for a typical midlatitude case. Camera designations are "A," "B," "C," and "D" for the four pairs of cameras viewing at shallow through steep viewing angles, respectively, "f" for forward looking, "a" for aft-looking, and "An" for nadir-viewing cameras.

Kahn et al., JGR 2001

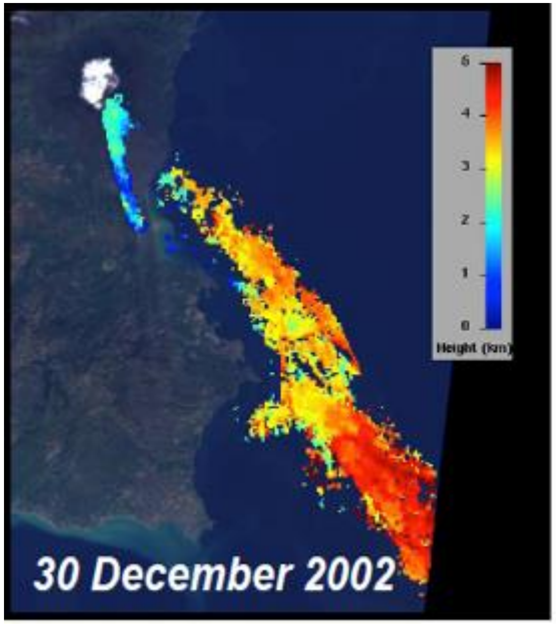
Mount Etna Plume Height and Eruption Style from MISR

Scollo, S. R.A. Kahn, D.L. Nelson, M. Coltelli, D.J. Diner, M.J. Garay, and V.J. Realmuto
MISR observations of Etna volcanic plumes. *J. Geophys. Res*. 2012



MISR nadir-viewing, true-color image showing Etna, with stereo-derived plume height superposed

29 Sept. 2006 – MISR retrieved mostly small spherical particles, indicating a sulfate/water-dominated plume



MISR stereo heights for the ash-dominated plume on 30 December 2002

Indications of Eruption Strength:

- ***Plume Height*** from MISR stereo imaging
- ***Ash to Sulfate/Water particle AOD ratio*** from MISR-retrieved particle shape and size

Mount Etna Plume Height and Eruption Style from MISR

[§]Etna Eruption Time (UTC)	Mean AOD	AOD Range	AOD Sph. Fraction Mean	AOD Sph. Fract. Range	Small	Med	Large
***Ash*-Dominated, Both MISR & Surface Obs.**			**Mostly *Large*, *Non-Spherical***				
27 Oct 2002 at 10:00[$]	0.31	[0.04 0.58]	0.42	[0.1 1]	0.31	0.23	0.46
23 Dec 2002 at 09:54	0.11	[0.09 0.12]	0.43	[0.4 1]	0.40	0.11	0.49
30 Dec 2002 at 10:04[$]	0.11	[0.04 0.14]	0.76	[0 1]	0.35	0.16	0.49
***Sulfate/Water*-Dominated, Both MISR & Surface Obs.**			**Mostly *Small*, *Spherical***				
29 July 2001 at 10:01	0.18	[0.15 0.25]	0.93	[0.6 1]	0.77	0.09	0.13
23 Nov 2002 at 09:42[$]	0.13	[0.07 0.19]	0.97	[0.2 1]	0.56	0.24	0.20
08 Jan 2003 at 09:54	0.15	[0.13 0.16]	0.95	[0.8 1]	0.49	0.08	0.43
29 Sept 2006 at 09:52	0.22	[0.15 0.26]	0.87	[0.6 1]	0.75	0.13	0.12
16 Nov 2006 at 09:46	0.08	[0.05 0.13]	0.94	[0.6 1]	0.67	0.08	0.25
25 Nov 2006 at 09:46	0.10	[0.05 0.15]	1	[1 1]	0.61	0.03	0.36
Particle Type Surface Validation Data Lacking							
23 May 2000 at 10:08[$]	0.36	[0.26 0.38]	0.25	[0.2 0.4]	0.23	0.35	0.42
01 Jun 2000 at 10:02	0.14	[0.03 0.22]	0.89	[0.4 1]	0.72	0.15	0.13

[§] AOD Sph. Fraction Mean = Mean MISR-retrieved green band AOD value attributed to spherical particles
AOD Sph. Fract. Range = Range of MISR-retrieved green band AOD fraction attributed to spherical particles
Small = MISR-retrieved green-band AOD fraction of particles having small size (<0.35 μm radius)
Med = MISR-retrieved green-band AOD fraction of particles having medium size (0.35 < 0.7 μm radius)
Large = MISR-retrieved green-band AOD fraction of particles having large size (>0.7 μm radius)
[$] Volcanic ash detected by MODIS

Scollo et al., *JGR* 2012

MISR Research Aerosol Retrieval

MISR components & Mixtures

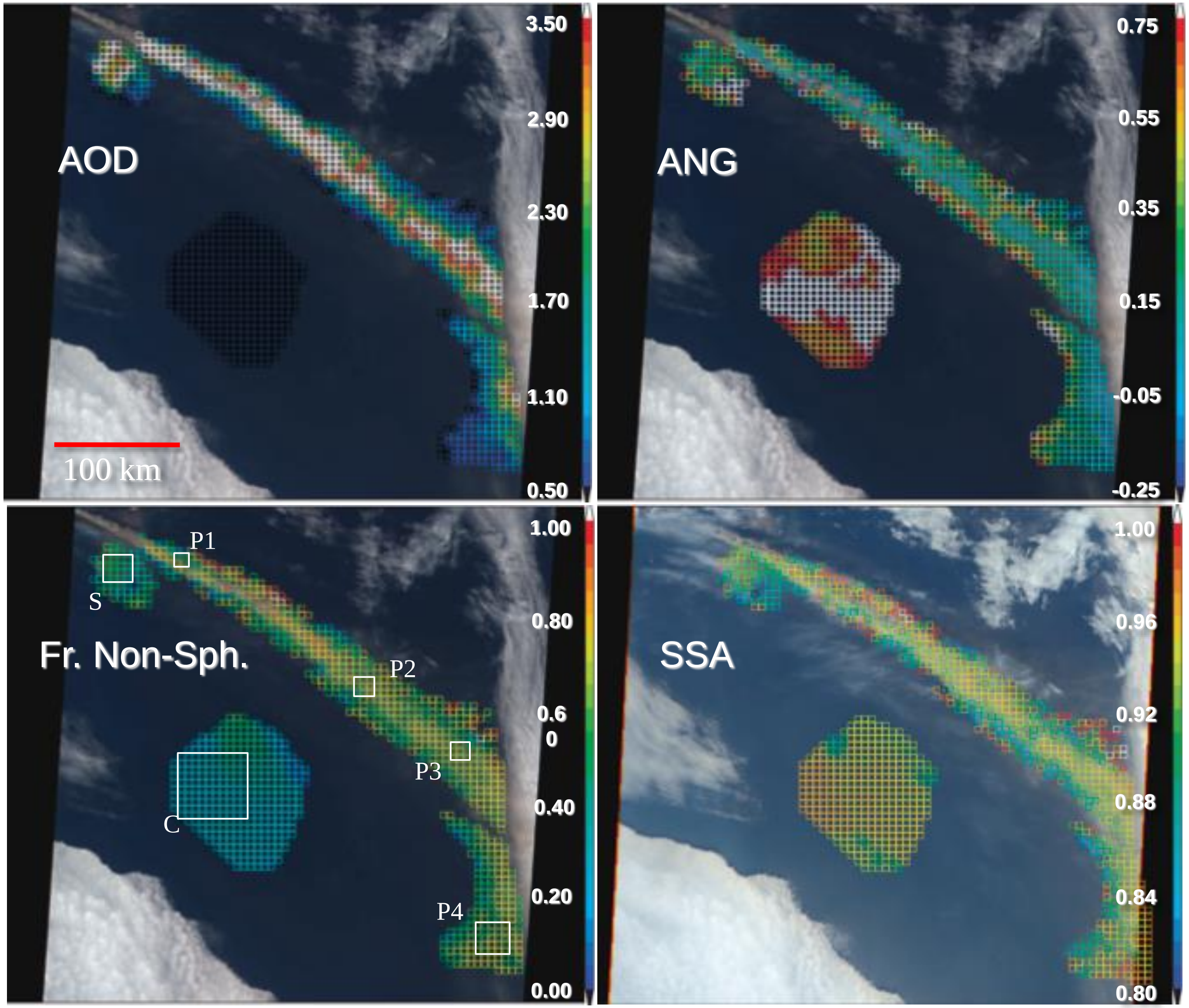
32 Components, 1200 mixing groups, 343200 mixtures

#	Component Name	r_1 (μm)	r_2 (μm)	r_c (μm)	σ	SSA (446)	SSA (558)	SSA (672)	SSA (866)	AOT(446)/ AOT(558)	AOT(672)/ AOT(558)	AOT(867)/ AOT(558)	g (558)	Particle Size/ Shape Category
	Spherical Non-Absorbing Optical Models[1]													
1	sph_nonabsorb_0.12	0.003	0.75	0.06	1.70	1.00	1.00	1.00	1.00	1.54	0.66	0.35	0.61	Small Spherical
2	sph_nonabsorb_0.26	0.005	1.70	0.12	1.75	1.00	1.00	1.00	1.00	1.18	0.82	0.58	0.72	Small Spherical
3	sph_nonabsorb_0.57	0.008	3.81	0.24	1.80	1.00	1.00	1.00	1.00	0.98	0.99	0.91	0.72	Medium Spherical
4	sph_nonabsorb_1.28	0.013	8.88	0.50	1.85	1.00	1.00	1.00	1.00	0.96	1.04	1.10	0.73	Large Spherical
5	sph_nonabsorb_2.80	0.022	19.83	1.00	1.90	1.00	1.00	1.00	1.00	0.98	1.02	1.05	0.77	Large Spherical
	Spherical Absorbing Optical Models[1]													
6	sph_abs_0.12_ssa_green_0.80_steep	0.003	0.75	0.06	1.70	0.82	0.80	0.77	0.72	1.47	0.70	0.40	0.61	Small Spherical very strongly absorbing
7	sph_abs_0.12_ssa_green_0.85_steep	0.003	0.75	0.06	1.70	0.87	0.85	0.83	0.79	1.49	0.69	0.39	0.61	Small Spherical strongly absorbing
8	sph_abs_0.12_ssa_green_0.90_steep	0.003	0.75	0.06	1.70	0.91	0.90	0.89	0.85	1.51	0.68	0.38	0.61	Small Spherical moderately absorbing
9	sph_abs_0.12_ssa_green_0.95_steep	0.003	0.75	0.06	1.70	0.96	0.95	0.94	0.92	1.52	0.67	0.36	0.61	Small Spherical weakly absorbing
10	sph_abs_0.26_ssa_green_0.80_steep	0.005	1.69	0.12	1.75	0.79	0.80	0.80	0.79	1.17	0.84	0.61	0.75	Small Spherical very strongly absorbing
11	sph_abs_0.26_ssa_green_0.85_steep	0.005	1.69	0.12	1.75	0.84	0.85	0.85	0.84	1.17	0.83	0.60	0.74	Small Spherical strongly absorbing
12	sph_abs_0.26_ssa_green_0.90_steep	0.005	1.69	0.12	1.75	0.89	0.90	0.90	0.90	1.18	0.83	0.59	0.73	Small Spherical moderately absorbing
13	sph_abs_0.26_ssa_green_0.95_steep	0.005	1.69	0.12	1.75	0.95	0.95	0.95	0.95	1.18	0.82	0.58	0.73	Small Spherical weakly absorbing
14	sph_abs_0.57_ssa_green_0.80_steep	0.008	3.81	0.24	1.80	0.77	0.80	0.82	0.84	0.98	0.99	0.91	0.78	Medium Spherical very strongly absorbing
15	sph_abs_0.57_ssa_green_0.85_steep	0.008	3.81	0.24	1.80	0.82	0.85	0.87	0.89	0.98	0.99	0.91	0.76	Medium Spherical strongly absorbing
16	sph_abs_0.57_ssa_green_0.90_steep	0.008	3.81	0.24	1.80	0.88	0.90	0.91	0.93	0.98	0.99	0.91	0.75	Medium Spherical moderately absorbing
17	sph_abs_0.57_ssa_green_0.95_steep	0.008	3.81	0.24	1.80	0.94	0.95	0.96	0.96	0.98	0.99	0.91	0.74	Medium Spherical weakly absorbing
18	sph_abs_1.28_ssa_green_0.80_steep	0.013	8.88	0.50	1.85	0.77	0.80	0.83	0.86	0.96	1.04	1.09	0.78	Large Spherical very strongly absorbing
19	sph_abs_1.28_ssa_green_0.85_steep	0.013	8.88	0.50	1.85	0.82	0.85	0.87	0.90	0.96	1.04	1.09	0.77	Large Spherical strongly absorbing
20	sph_abs_1.28_ssa_green_0.90_steep	0.013	8.88	0.50	1.85	0.88	0.90	0.92	0.93	0.96	1.04	1.09	0.76	Large Spherical moderately absorbing
21	sph_abs_1.28_ssa_green_0.95_steep	0.013	8.88	0.50	1.85	0.94	0.95	0.96	0.97	0.96	1.04	1.10	0.74	Large Spherical weakly absorbing

#	Component Name	r_1 (μm)	r_2 (μm)	r_c (μm)	σ	SSA (446)	SSA (558)	SSA (672)	SSA (866)	AOT(446)/ AOT(558)	AOT(672)/ AOT(558)	AOT(867)/ AOT(558)	g (558)	Particle Size/ Shape Category
	Spherical Absorbing Optical Models[1]													
22	sph_abs_2.80_ssa_green_0.80_steep	0.022	19.83	1.00	1.90	0.77	0.80	0.82	0.85	0.98	1.02	1.05	0.83	Large Spherical very strongly absorbing
23	sph_abs_2.80_ssa_green_0.85_steep	0.022	19.83	1.00	1.90	0.83	0.85	0.87	0.89	0.98	1.02	1.05	0.81	Large Spherical strongly absorbing
24	sph_abs_2.80_ssa_green_0.90_steep	0.022	19.83	1.00	1.90	0.88	0.90	0.91	0.93	0.98	1.02	1.05	0.80	Large Spherical moderately absorbing
25	sph_abs_2.80_ssa_green_0.95_steep	0.022	19.83	1.00	1.90	0.94	0.95	0.96	0.97	0.98	1.02	1.05	0.79	Large Spherical weakly absorbing
	Dust Grains Optical Models[1]													
26	dust_grains_h1	0.10	1.0	0.50	1.50	0.92	0.98	0.99	1.00	0.90	1.07	1.08	0.71	Weakly absorbing grains
27	dust_grains_h4	0.10	1.0	0.50	1.50	0.72	0.91	0.98	0.99	0.90	1.07	1.10	0.72	Moderately absorbing grains
28	dust_grains_h10	0.10	1.0	0.50	1.50	0.98	0.80	0.94	0.98	1.05	1.09	1.16	0.72	Strongly absorbing grains
	Dust Spheroid Optical Model[1]													
29	dust_spheroids	0.10	6.0	1.00	2.00	0.81	0.90	0.97	0.98	0.99	1.02	1.05	0.77	Coarse Dust Spheroids
	Cirrus Optical Models[1,2]													
30	Baum_cirrus_De = 10 μm	2.0	9500.0	5.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.79	Cirrus
31	Baum_cirrus_De = 40 μm	2.0	9500.0	20.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.81	Cirrus
32	Baum_cirrus_De = 100 μm	2.0	9500.0	50.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.87	Cirrus

MISR Research Aerosol Retrievals

07 May 2010 Orbit 55238 Path 216 Blks 40-43 UT 12:39



Plume Particles

- Distinct from background
  - -- ***larger***, ***darker***
  - -- ***much higher AOD***
- ***Non-spherical*** dominated
- Brighten downwind
- Tend to decrease in size downwind

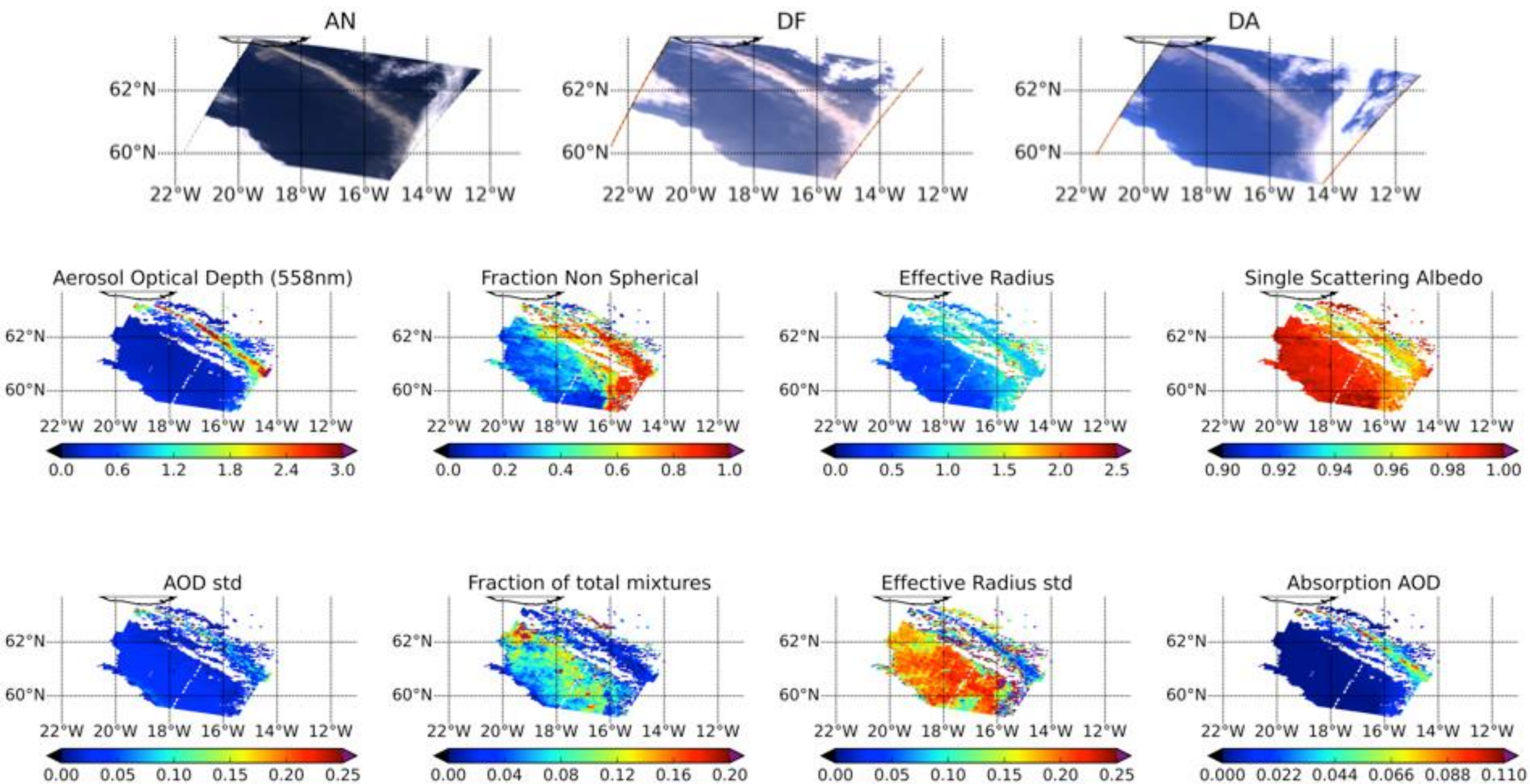
3.3 km retrievals

Kahn & Limbacher, ACP 2012

MISR Research Aerosol Retrievals

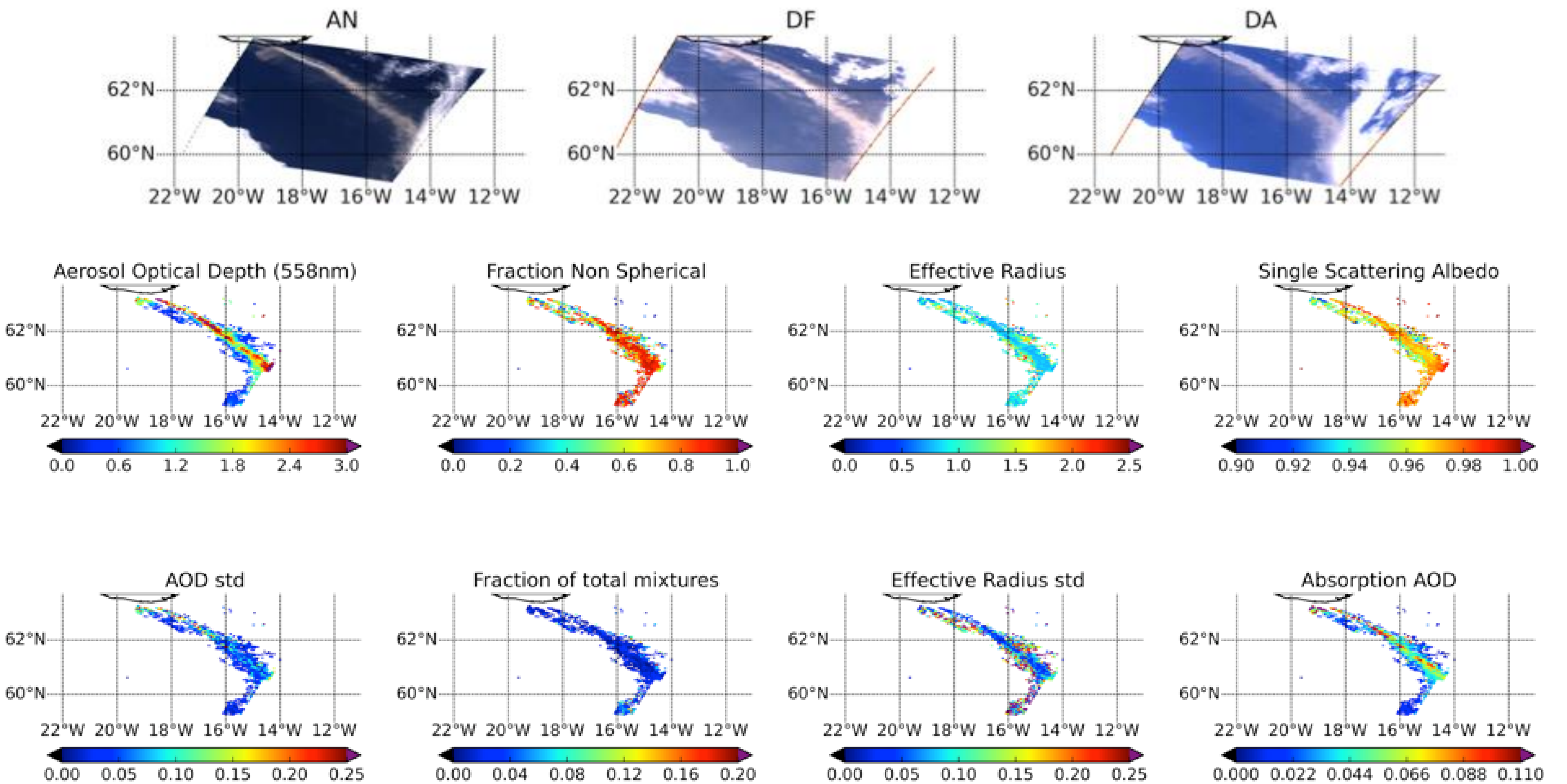
(AOD, particle properties)

07 May 2010 Orbit 55238 Path 216 Blks 40-42 UT 12:39



4.4 km retrievals

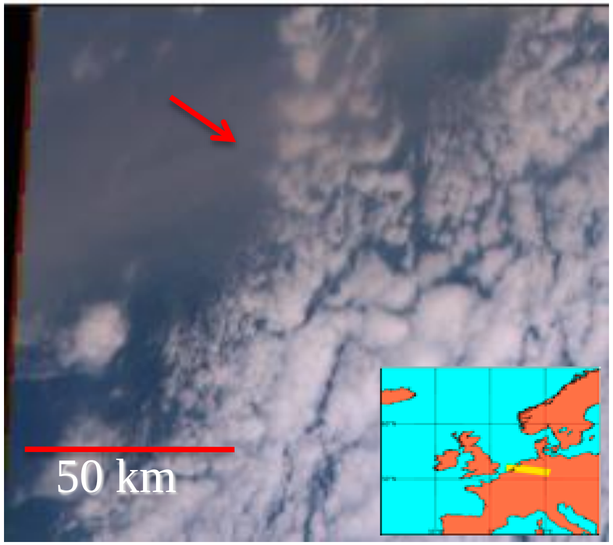
MISR Research Aerosol Retrievals
(AOD, particle properties)
07 May 2010 Orbit 55238 Path 216 Blks 40-42 UT 12:39



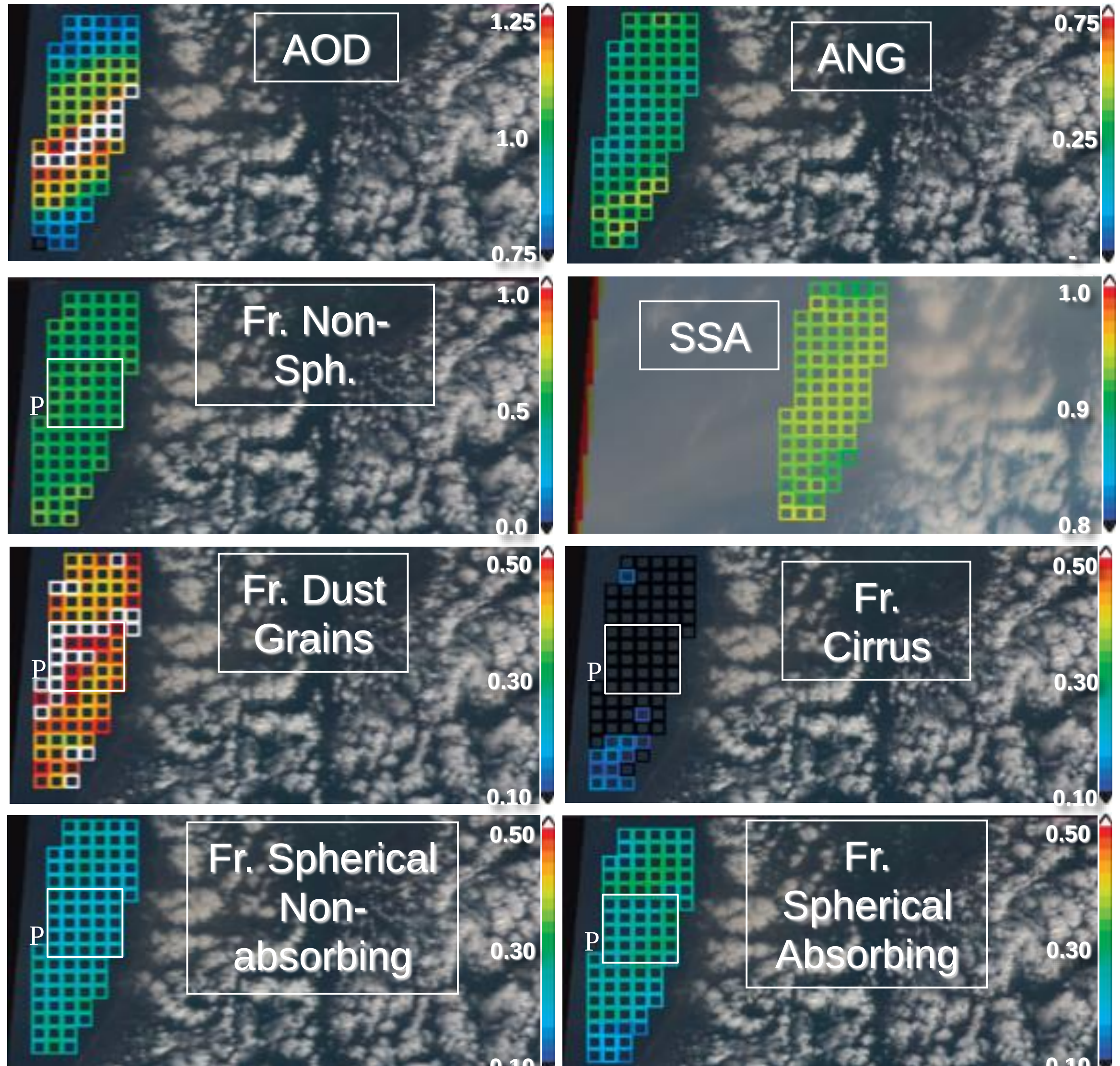
4.4 km retrievals

MISR Research ***Aerosol Retrievals***

16 April 2010 *Orbit 54931 Path 197 Blk 49 UT 10:45*



- ***1-2 days downwind*** of Iceland volcano source
- Distinctly ***high AOD*** (peak >1.25)
- Retrieved ~50% AOD ***non-spherical*** dust grains
- ***Medium*** particles ~ no "cirrus"
- Model ***back-trajectory needed*** to identify plume confidently

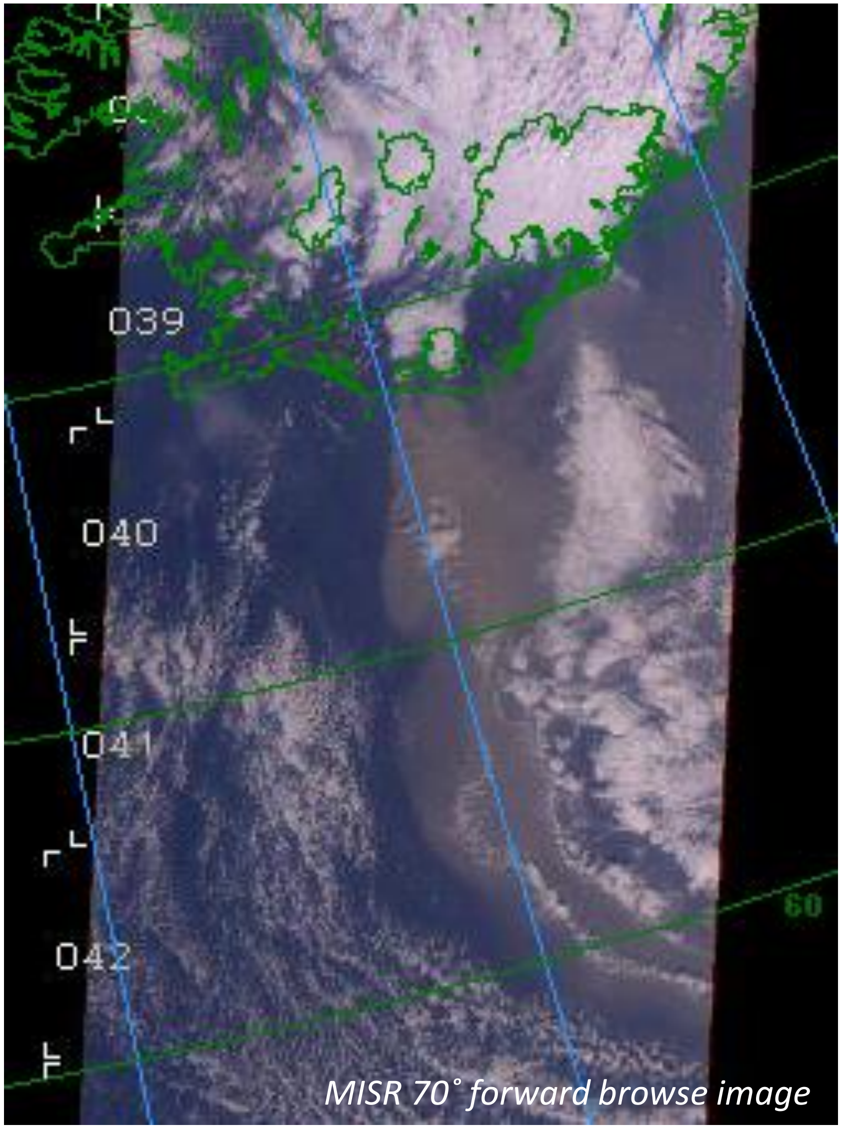


Kahn & Limbacher, ACP 2012

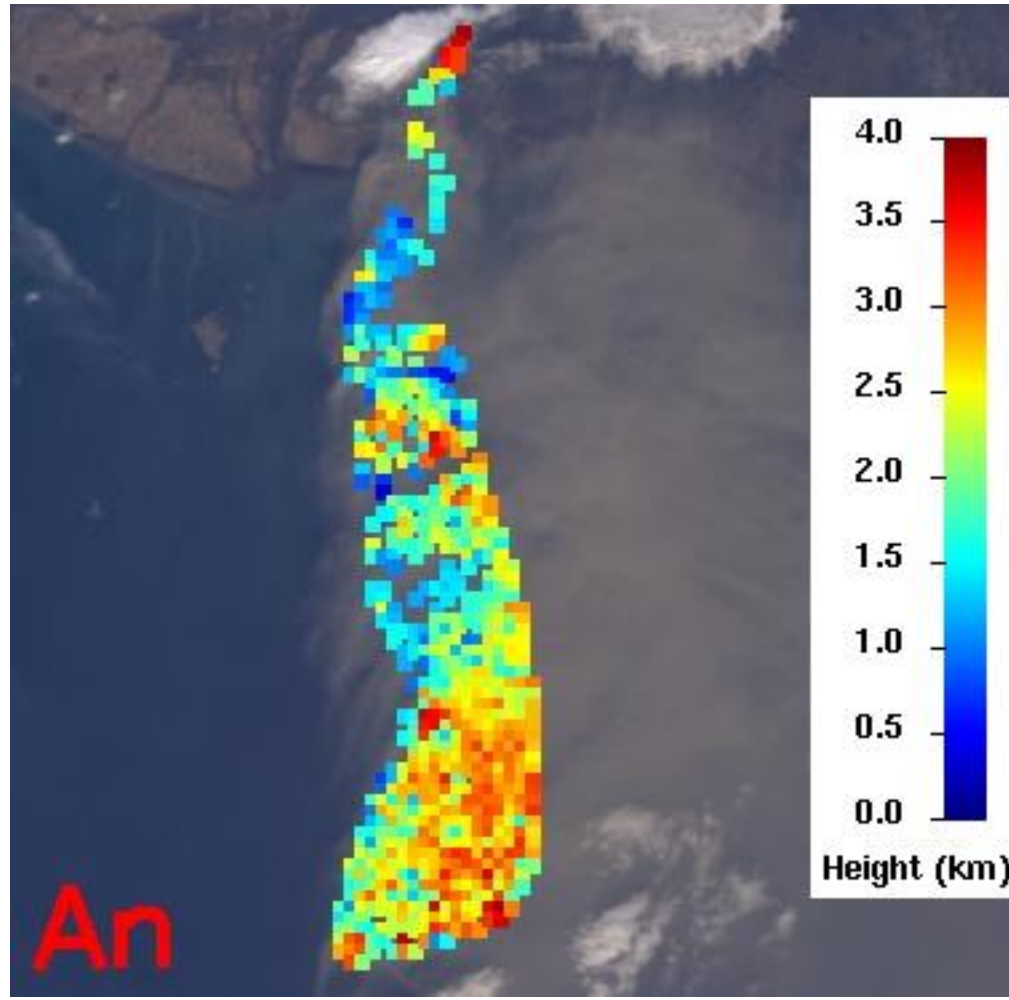
3.3 km retrievals

Grimsvötn Volcano

19 April 2010 Orbit 54976 Path 218 Blks 39-42 UT 12:51



MISR 70˚ forward browse image

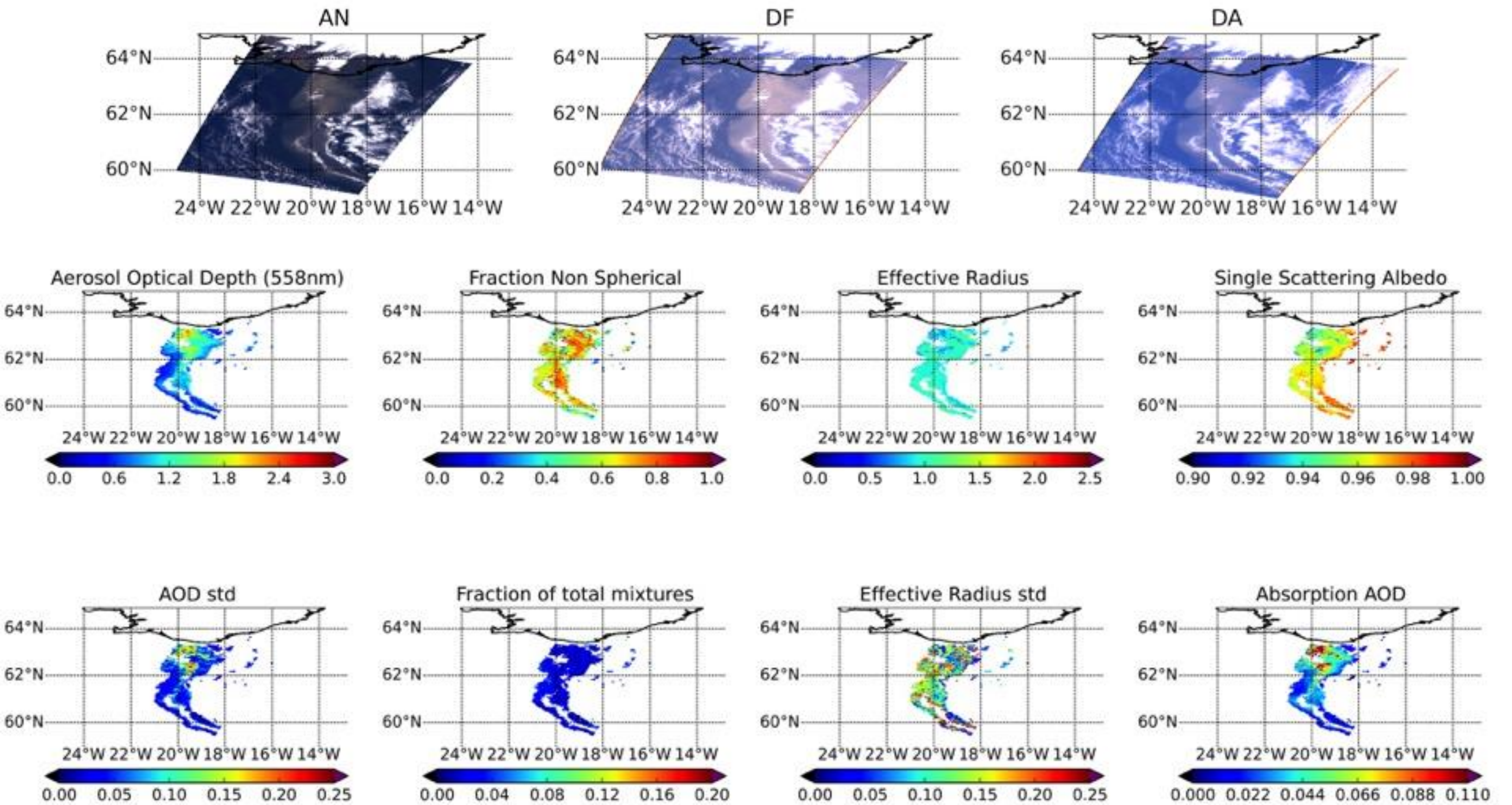


MINX Stereo Height Map

MISR Research Aerosol Retrievals

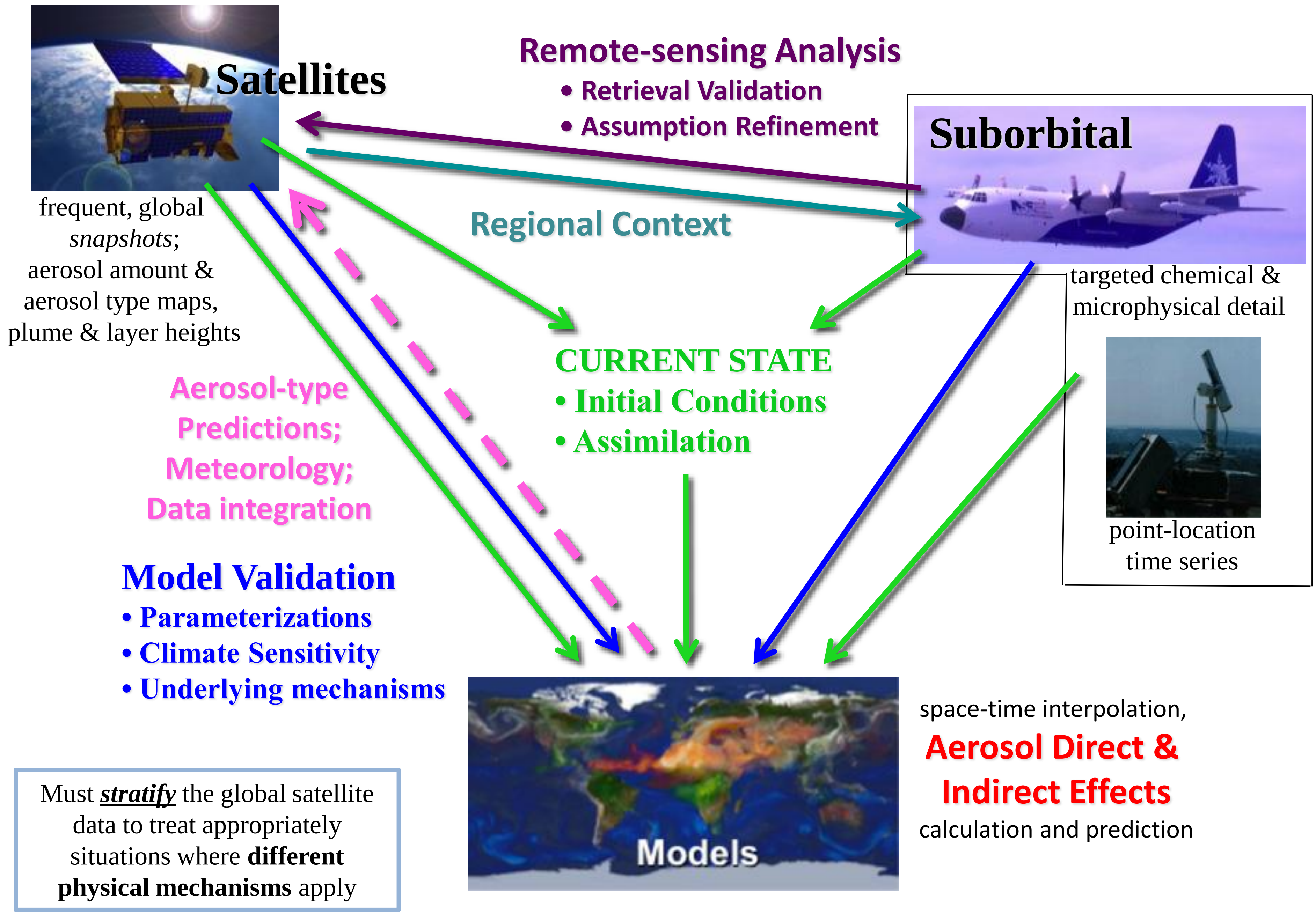
(AOD, particle properties)

19 April 2010 Orbit 54976 Path 218 Blks 39-42 UT 12:51



MISR Summary

- ***~ Weekly global coverage*** – good primarily for retrospective analysis, but not for real-time analysis in most cases
- ***AOD, Plume Height, Ash/Sulfate*** (aerosol type) are all available from MISR where coverage of volcanic plumes exists
- Free troposphere aerosols tend to be transported long distances in relatively thin ***layers of relative atmospheric stability***
- Good ***optical analogs for volcanic ash*** at visible wavelengths are ***needed*** as input to the satellite retrievals



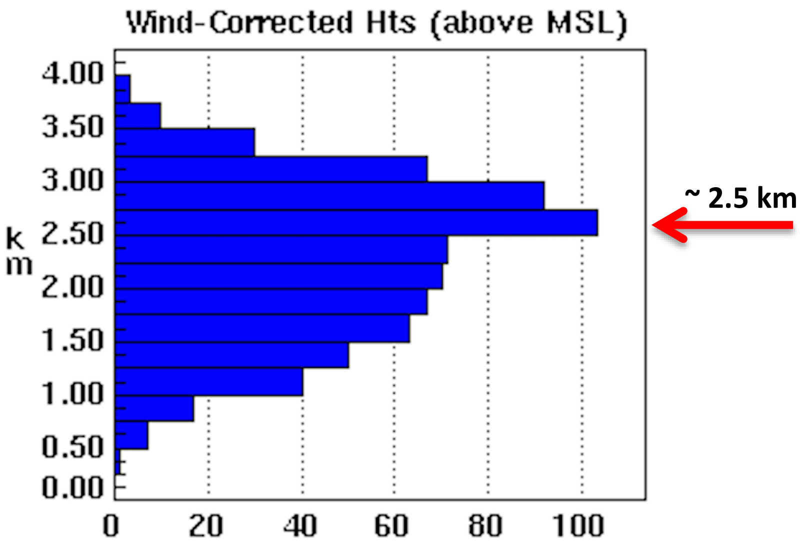
Adapted from: Kahn, Survy. Geophys.

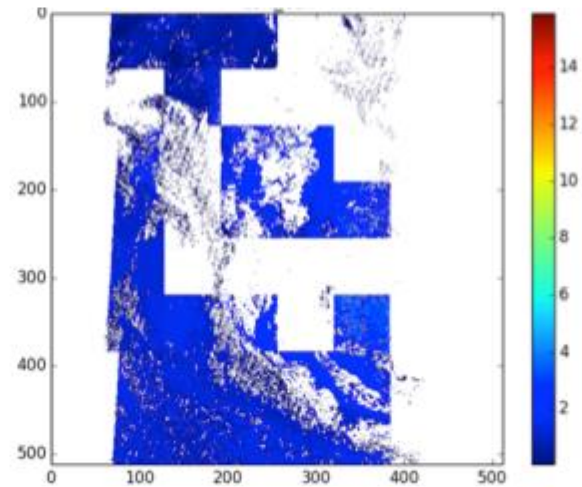
Backup Slides

Grimsvötn Volcano

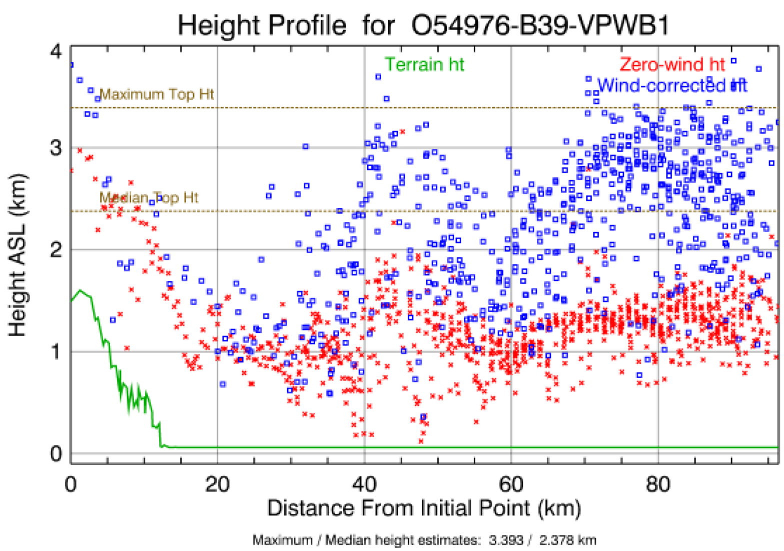
MINX Stereo Heights & Winds

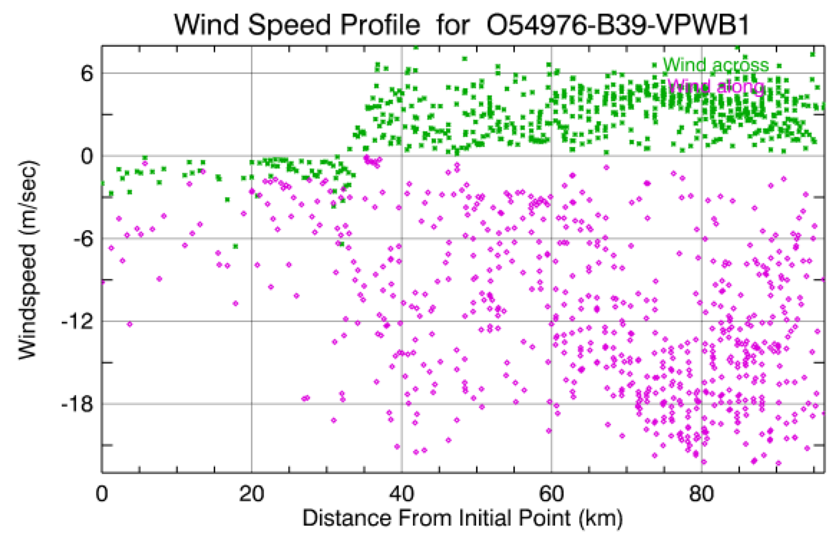
19 April 2010 Orbit 54976 Path 218 Blks 39-42 UT 12:51





*MISR **Standard** Stereo Height Map*





MISR Research Aerosol Retrievals

(AOD, particle properties)

19 April 2010 Orbit 54976 Path 218 Blks 39-42 UT 12:51